

# **Snow Cover Mapping for Yield Forecasts and Photovoltaic System Monitoring**

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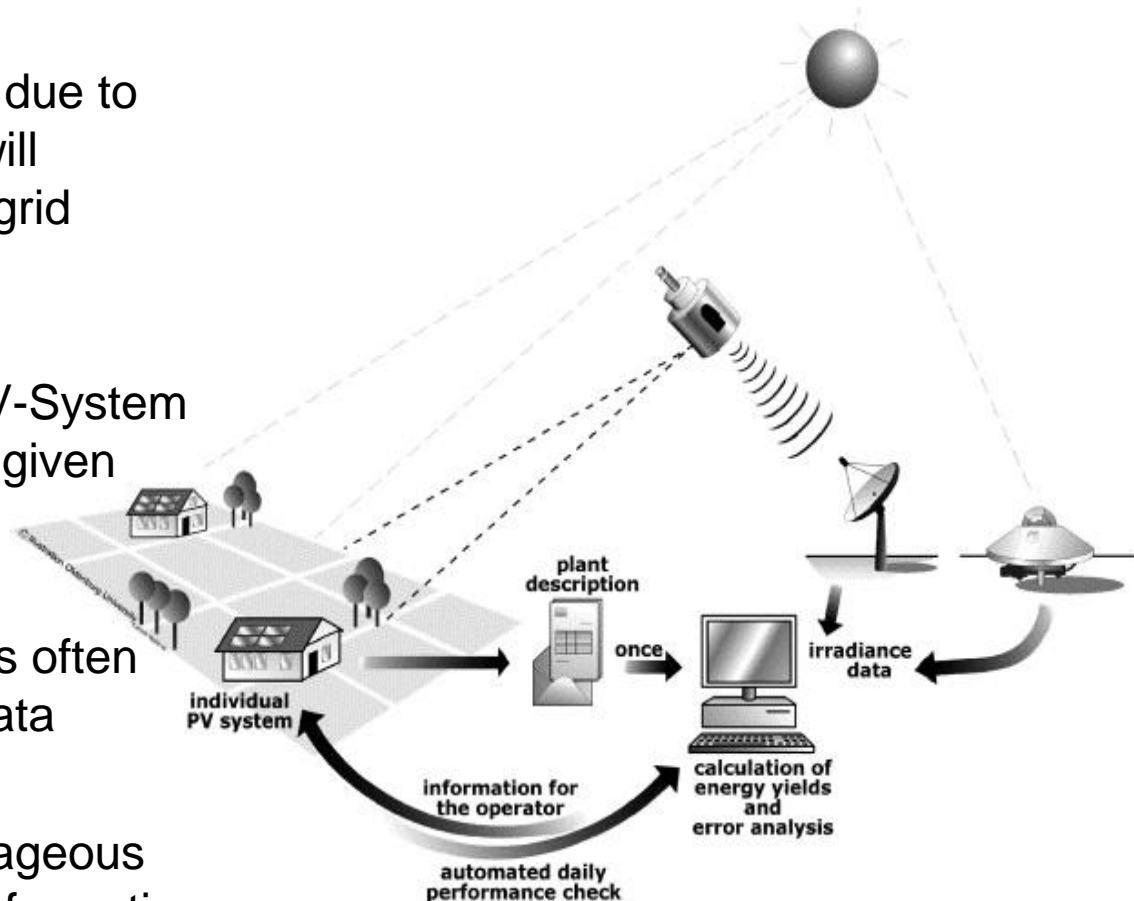
# Outline

- Influence of Snow on Monitoring PV Systems
  - Monitoring of PV Systems
  - Effects of a Snow Cover
  - Available Snow Cover Datasets
  - Validation of the Datasets
  
- Snow Cover Mapping for Yield Prognosis
  - General Information on Yield Prognosis
  - Satellite Record Used for the Snow Cover Maps
  - Snow Cover Maps for Europe and the US



# Monitoring PV-Systems

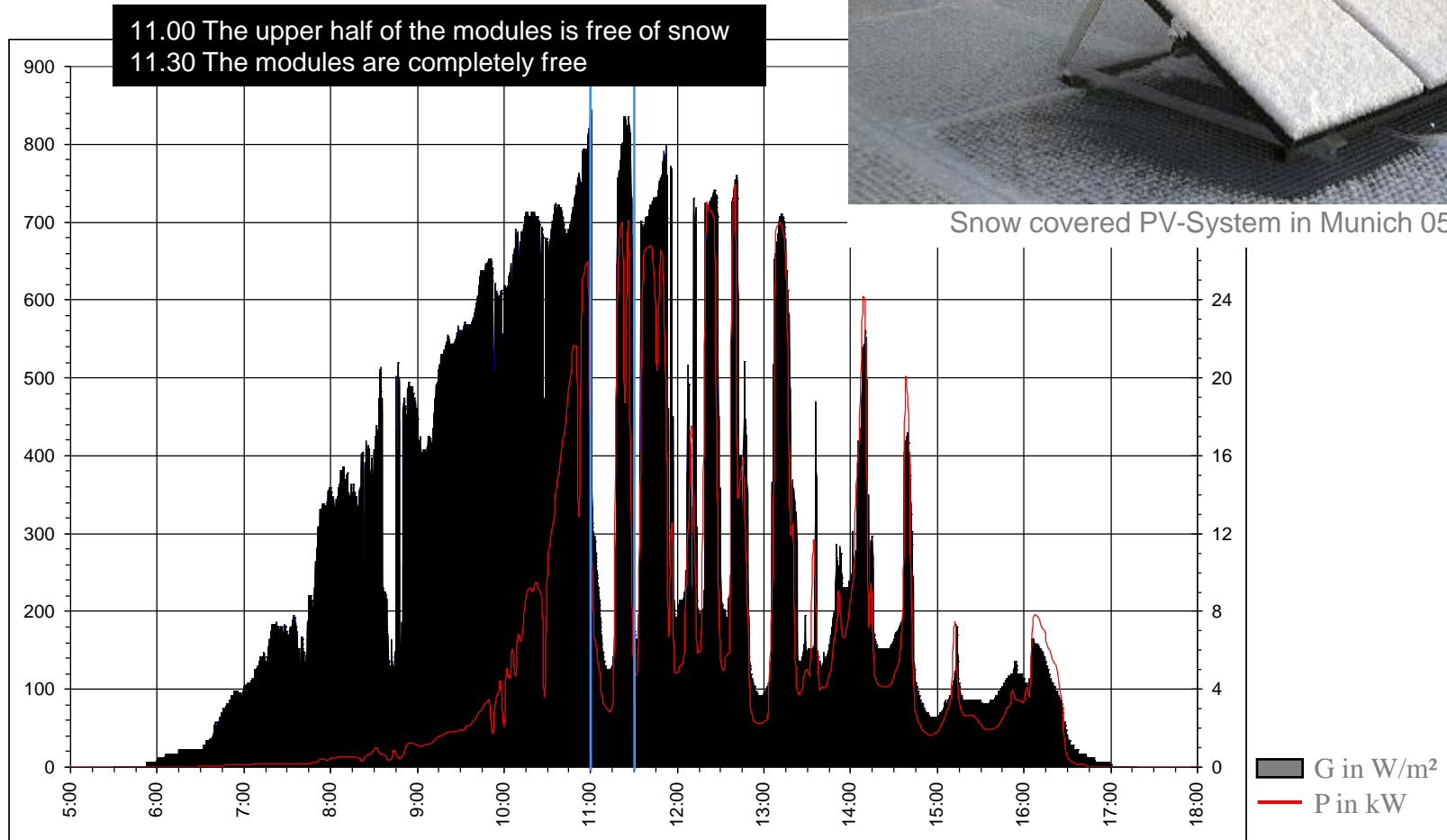
- Monitoring is important due to financial reasons and will become necessary for grid stability
- The actual yield of a PV-System can be calculated for a given solar radiation
- Irradiance information is often derived from satellite data
- Satellite data is advantageous because of its spatial information



# Effects of Snow Cover



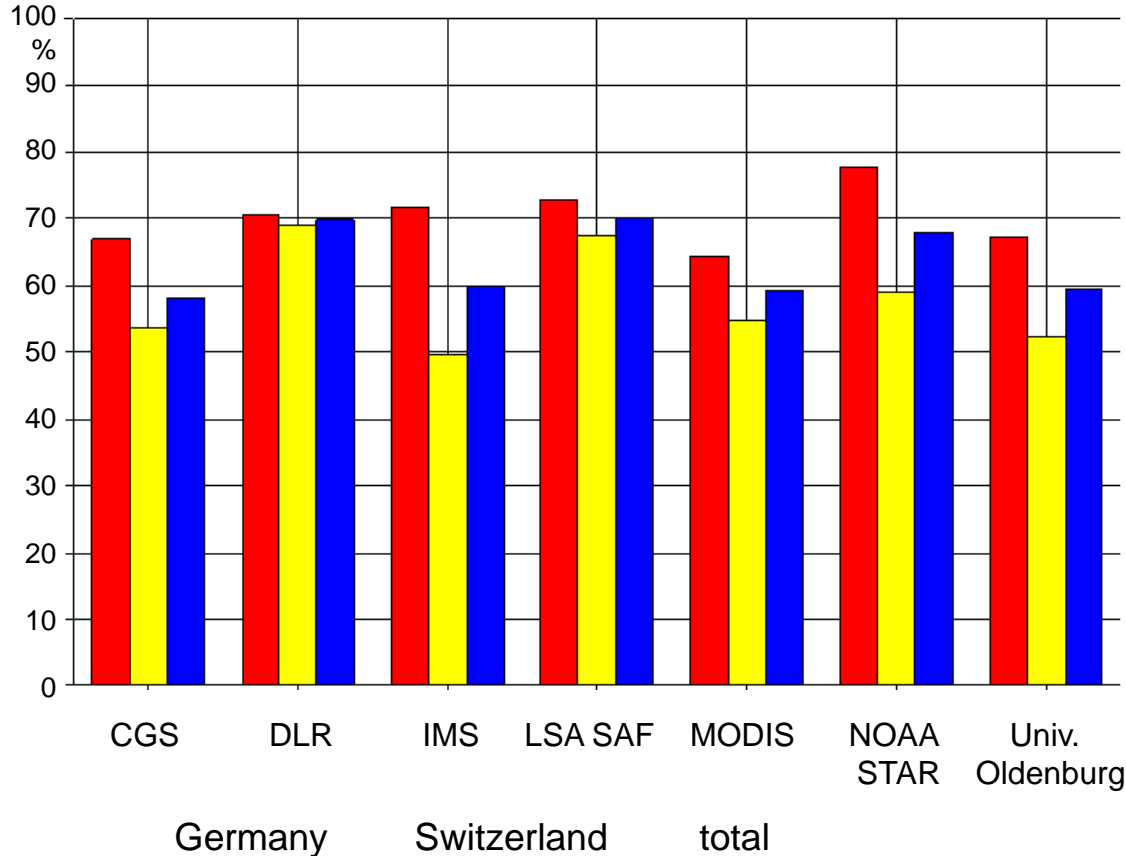
Snow covered PV-System in Munich 05.03.2008



<b>Provider</b>	<b>Satellit</b>	<b>Sensor</b>	<b>Resolution</b>	<b>Coverage</b>	<b>Data Type</b>
Automated snow mapping system (NOAA – STAR)	MSG	SEVIRI	4 km	Europe	Binär
Carl von Ossietzky Universität Oldenburg	MSG	SEVIRI	On demand	Europe	CSV
Carlo Gavazzi Space (CGS)	Terra	MODIS	250 m	European Alps	Binär
Deutsches Zentrum für Luft u. Raumfahrt – DLR	MSG	SEVIRI	4 km @ Nadir	Europe, Africa, South America	HDF
IMS NSIDC	Aqua, Terra, MSG, POES	MODIS, SEVIRI, AVHRR, SSM/I, AMSU	4 km	Northern Hemisphere	GeoTIF ASCII
LSA SAF (EUMETSAT)	MSG	SEVIRI	4 km @ Nadir	Europe, Africa, South America	HDF 5
MODIS (MOD10A1)	Terra	MODIS	500 m	Worldwide	HDF EOS



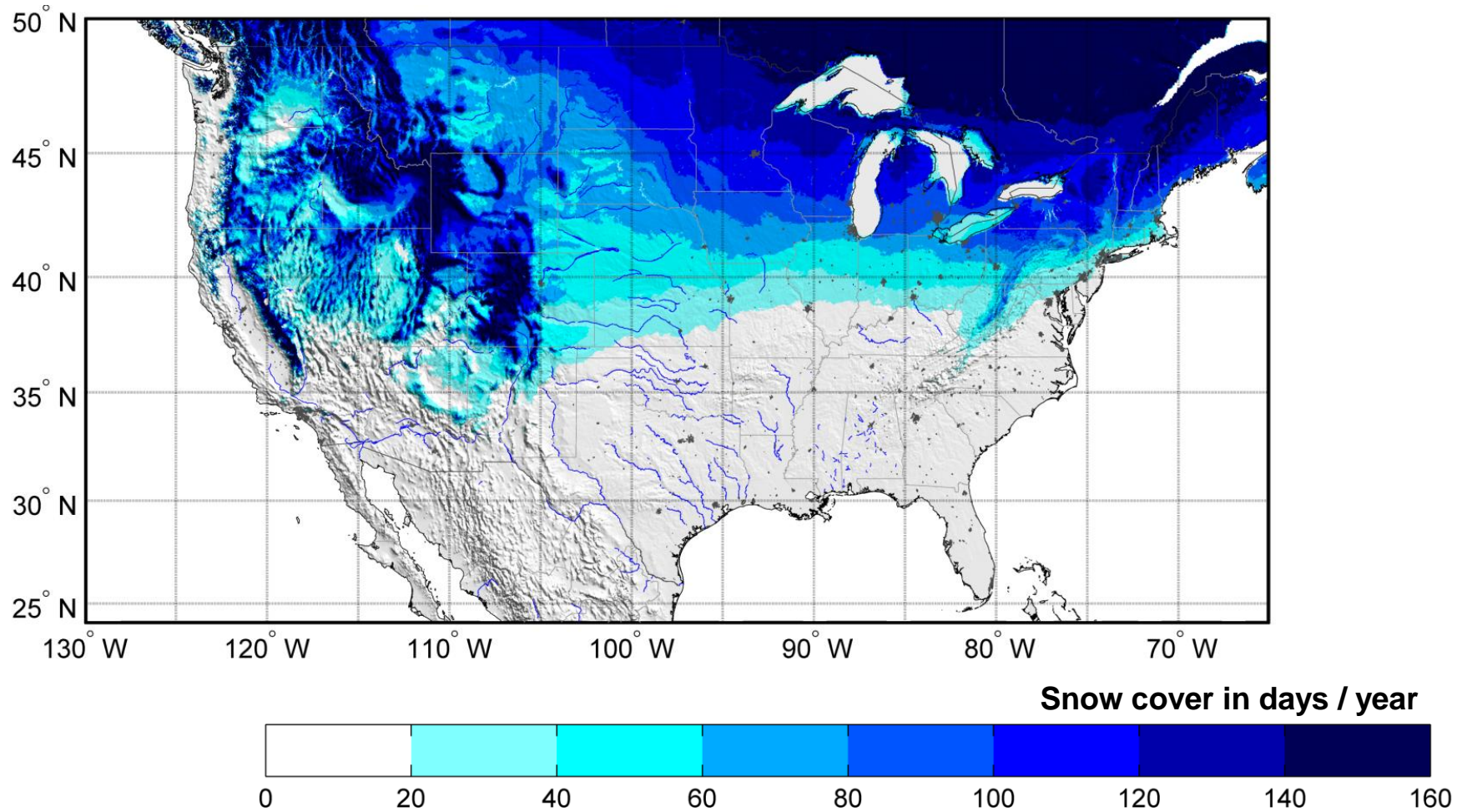
# Classification Accuracy



- LSA SAF and DLR show the best overall accuracy
- Both show the benefit of the high temporal resolution of Meteosat
- Global products show good values in Germany but have a low performance in difficult areas like Switzerland.

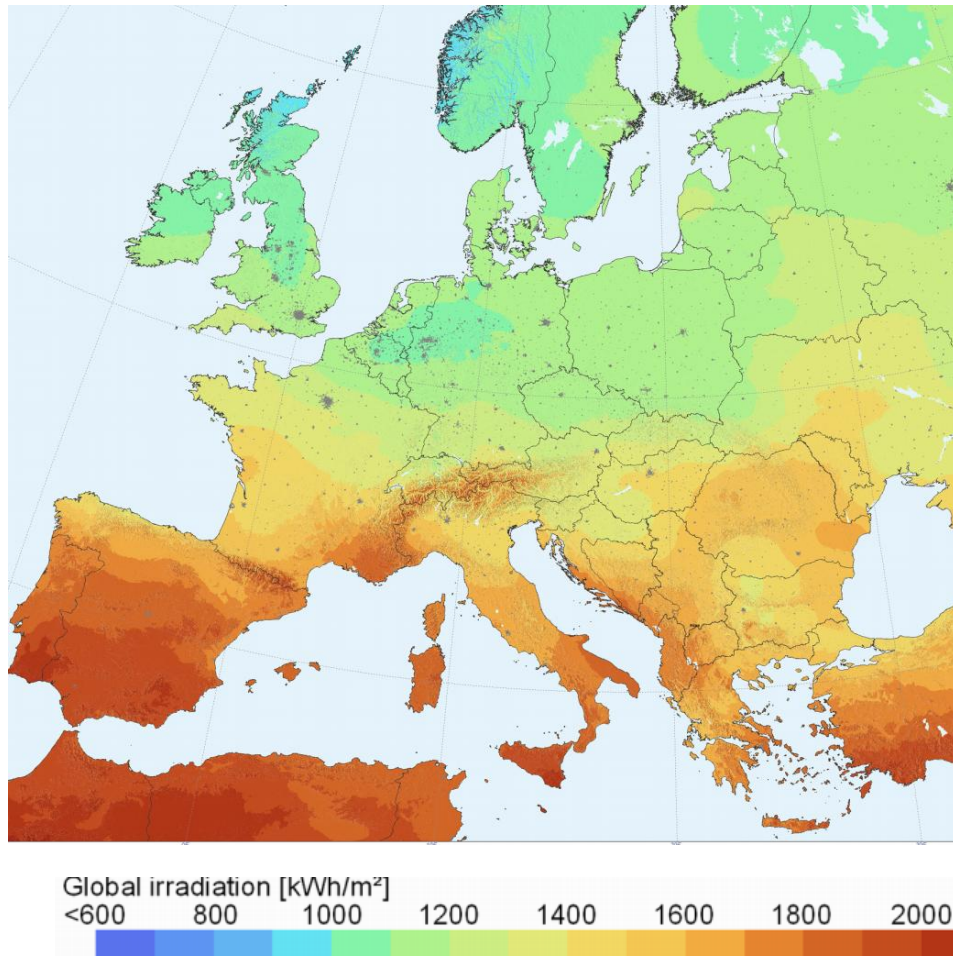


# Snow Cover Maps





# Yield Prognosis



- For a yield prognosis it is common to use long time series of global irradiation data
- Data based on satellite and / or ground measurements
- A minimum of 5 years is recommended for significant results
- Hardly information on snow cover available





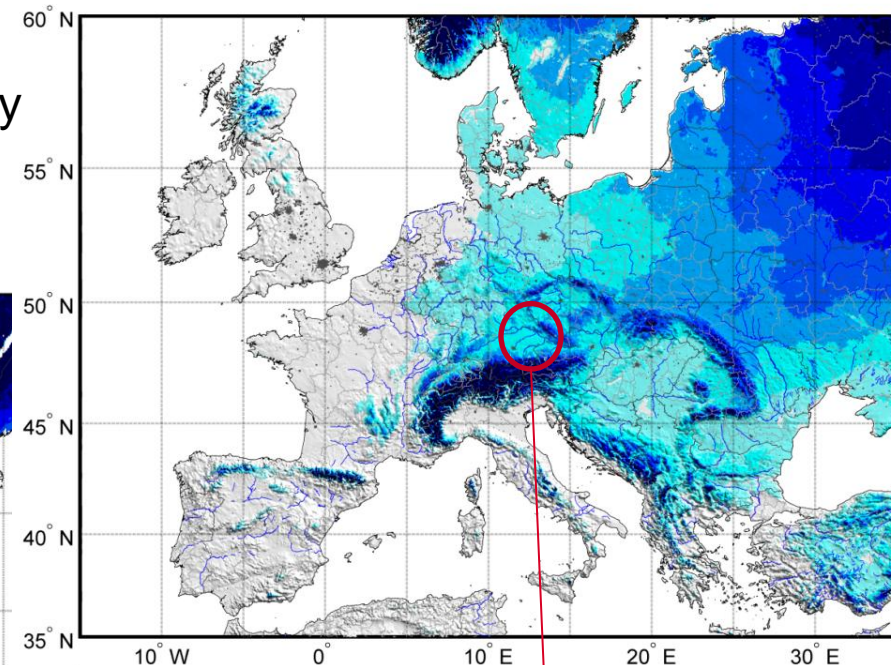
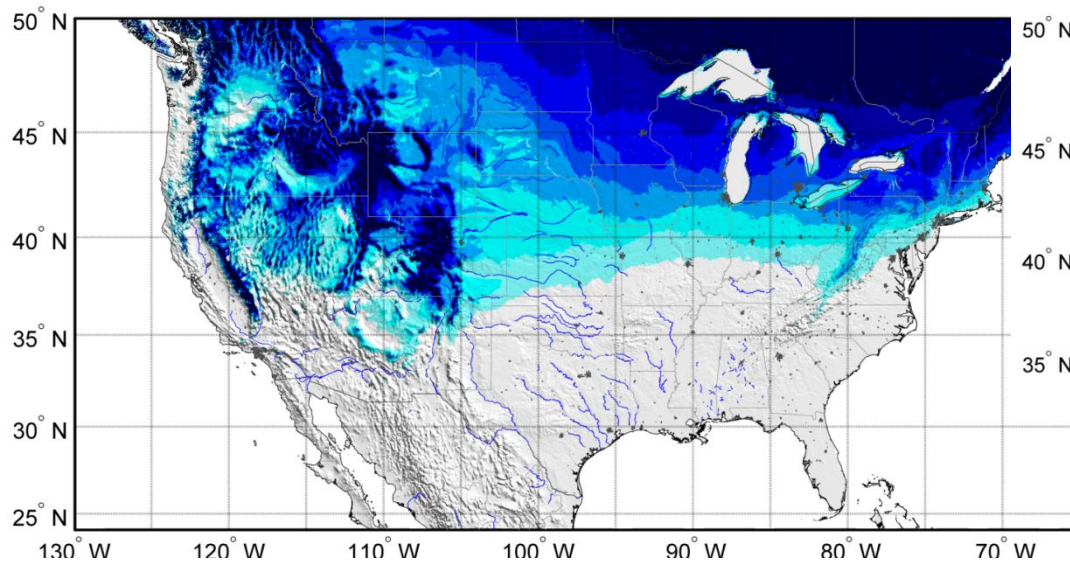
# Data Used for the Snow Cover Maps

- NOAA / NESDIS
- Interactive Multisensor Snow and Ice Mapping System (IMS)
  - Snow Cover Mapping since 1966
  - Daily data on a 24 km x 24 km resolution since 1997
  - Daily data on a 4 km x 4 km resolution since 2004

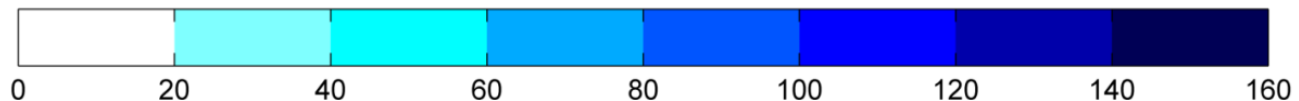


# Yearly Snow Cover Maps

- Between 20 and 60 snow covered days in areas used for PV in Germany
- Considerably more snow in the north of the US

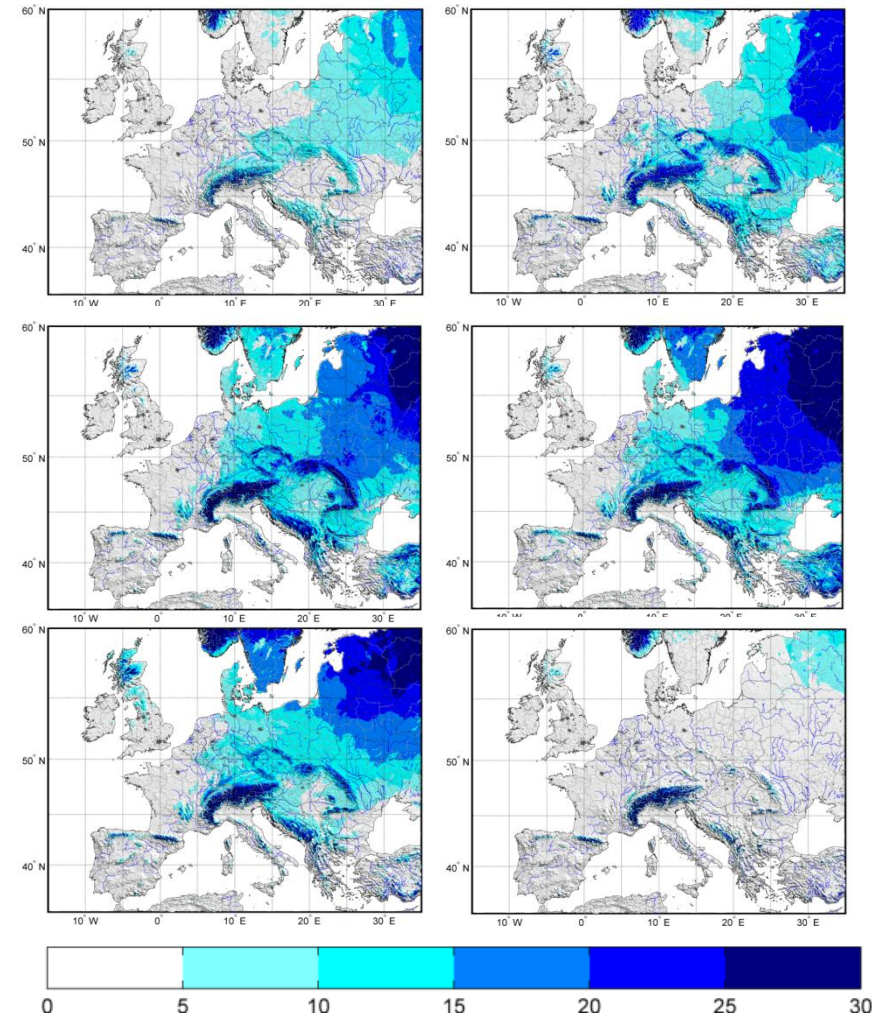


Bavaria: ~ 4 GW of PV installed  
3,5 % of the yearly consumption



# Monthly Snow Cover in Europe

- Snow cover from November till March
- Little losses in November because there are only few snow covered days
- Small losses in December and January due to low zenith angle
- Most losses appear in March since there is considerable radiation and snow cover






16.0

2008-03-05 CET 09:56:46

# Thank you for your attention



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# Backup



# Validation of the Datasets

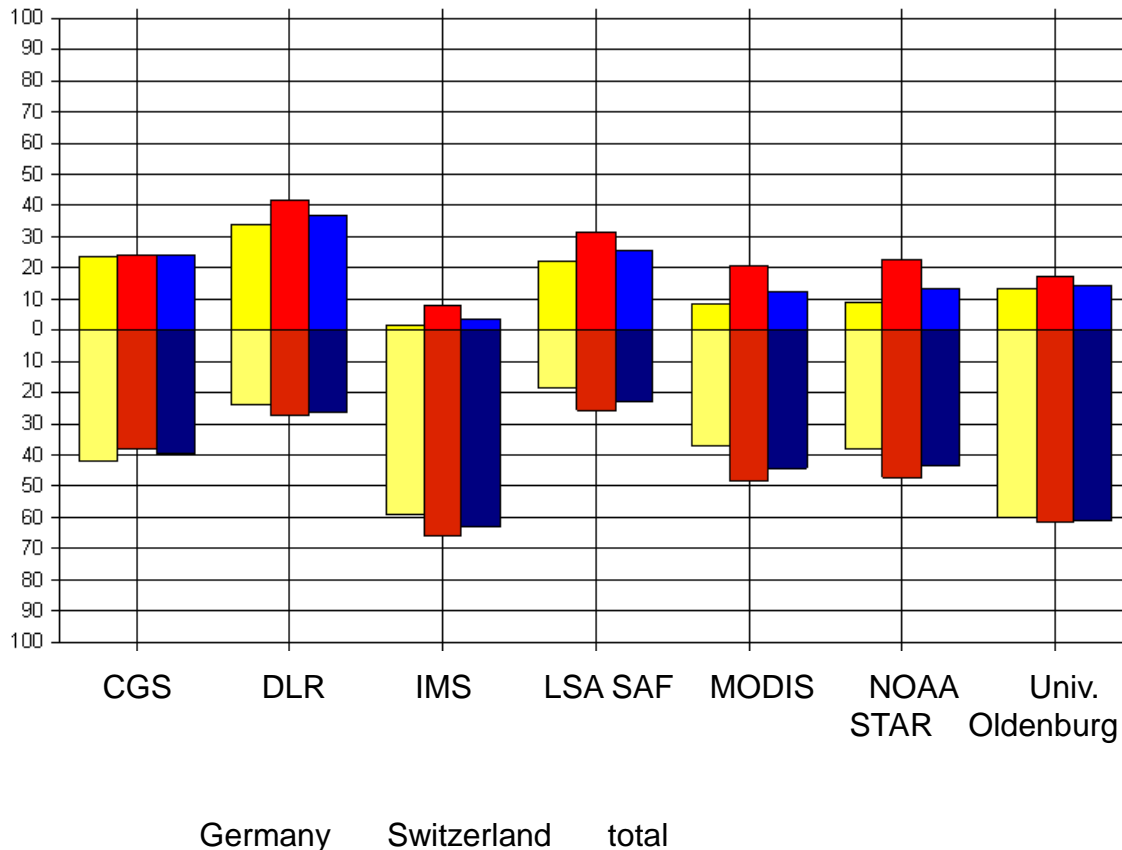
Schweiz		
Name	Länge	Breite
Aigle	6° 55' O	46° 20' N
Altdorf	8° 38' O	46° 52' N
Basel-Binningen	7° 35' O	47° 32' N
Bern-Liebefeld	7° 25' O	46° 56' N
Buchs-Suhr	8° 4' O	47° 23' N
Chur-Ems	9° 32' O	46° 52' N
Fahy	6° 56' O	47° 25' N
Genève-Cointrin	6° 7' O	46° 15' N
Zürich	8° 34' O	47° 23' N
Lugano	8° 58' O	46° 0' N
Luzern	8° 18' O	47° 2' N
Magadino	8° 53' O	47° 00' N
Payeme	6° 57' O	46° 49' N
Sion	7° 20' O	46° 13' N
St. Gallen	9° 24' O	47° 26' N

Deutschland		
Name	Länge	Breite
Weissenburg/Bay	10° 58' O	49° 1' N
Nürnberg-Kra.	11° 3' O	49° 30' N
Straubing	12° 34' O	48° 50' N
Augsburg-Mühlheim	10° 57' O	48° 26' N
Landsberg	10° 54' O	48° 4' N
Ingolstadt	11° 32' O	48° 43' N
München-Stadt	11° 33' O	48° 10' N
Fürstenzell	13° 21' O	48° 33' N
Konstanz	9° 11' O	47° 41' N
Obersdorf	10° 17' O	47° 24' N
Altenstadt	10° 52' O	47° 50' N
Hohenpeissenberg	11° 1' O	47° 48' N
Garmisch-Partenkirchen	11° 4' O	47° 29' N
Wendelstein	12° 1' O	47° 42' N





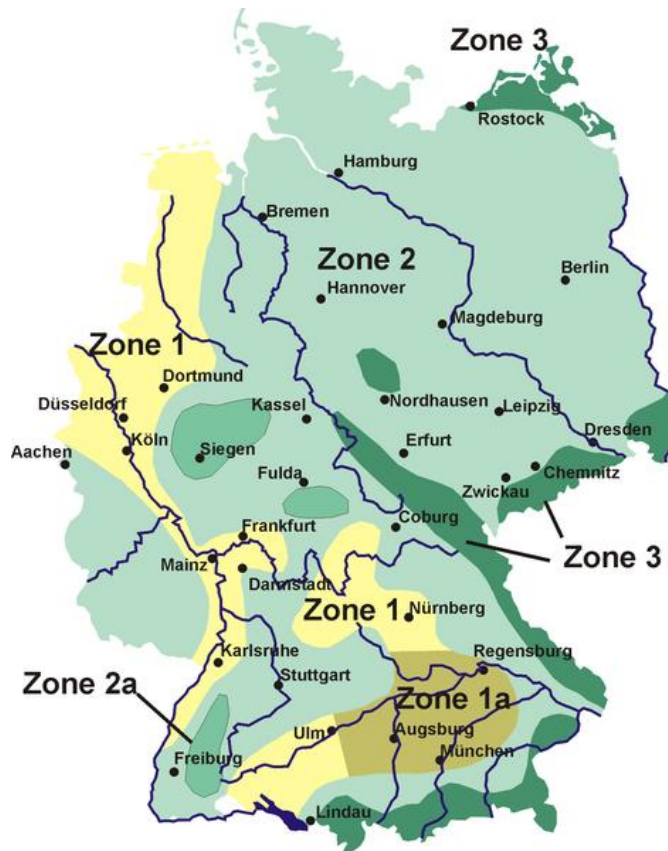
# Total Error



- *False Alarm Rate* (Snow not identified) upward
- *Error due to underestimation* (to much snow) downward
- The orientation around the zero line shows the handling of identified snow
- The error should be small and symmetrical
- LSA SAF has the most symmetrical pattern



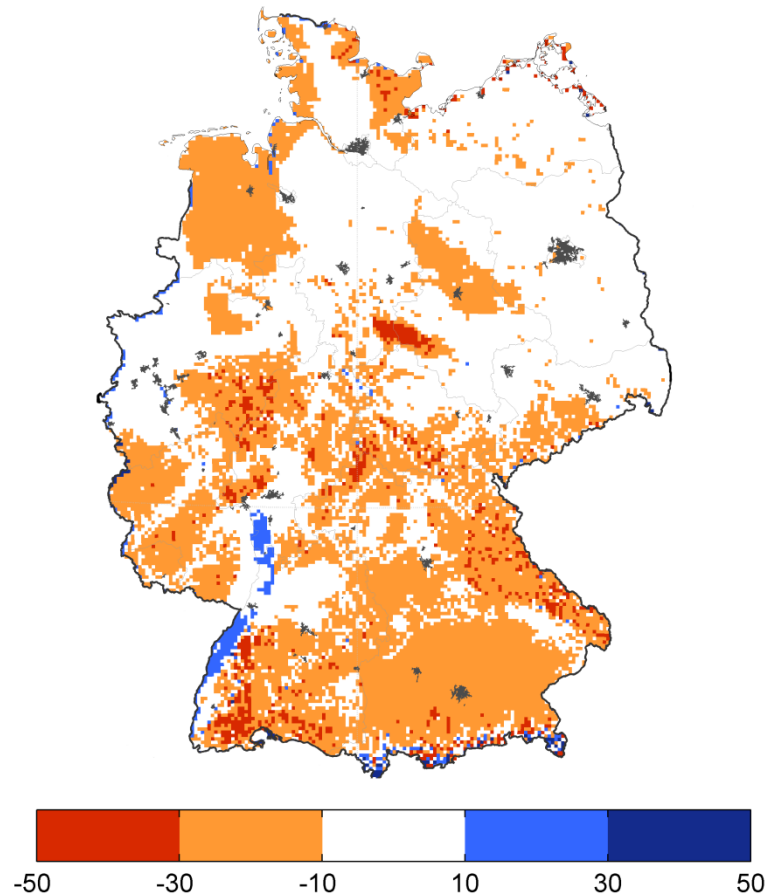
# Snow Load Maps



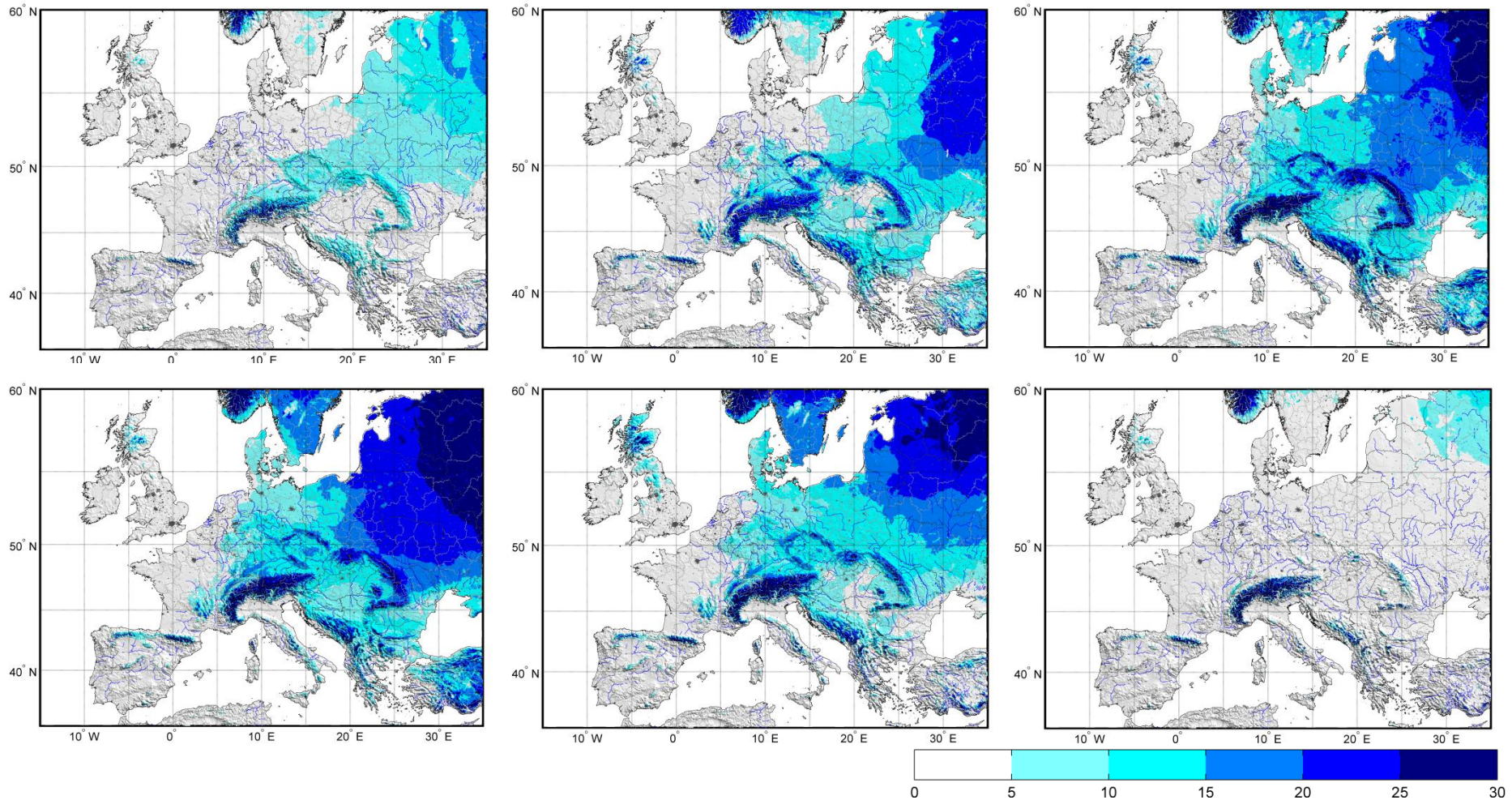
- Hardly information on snow cover duration available
- Snow load maps are often used for a rough estimation of losses
- The maps are not applicable as they show the maximum load and not the duration



# Validation in with Data of Germany's National Meteorological Service (DWD)



# Monthly Snow Cover in Europe



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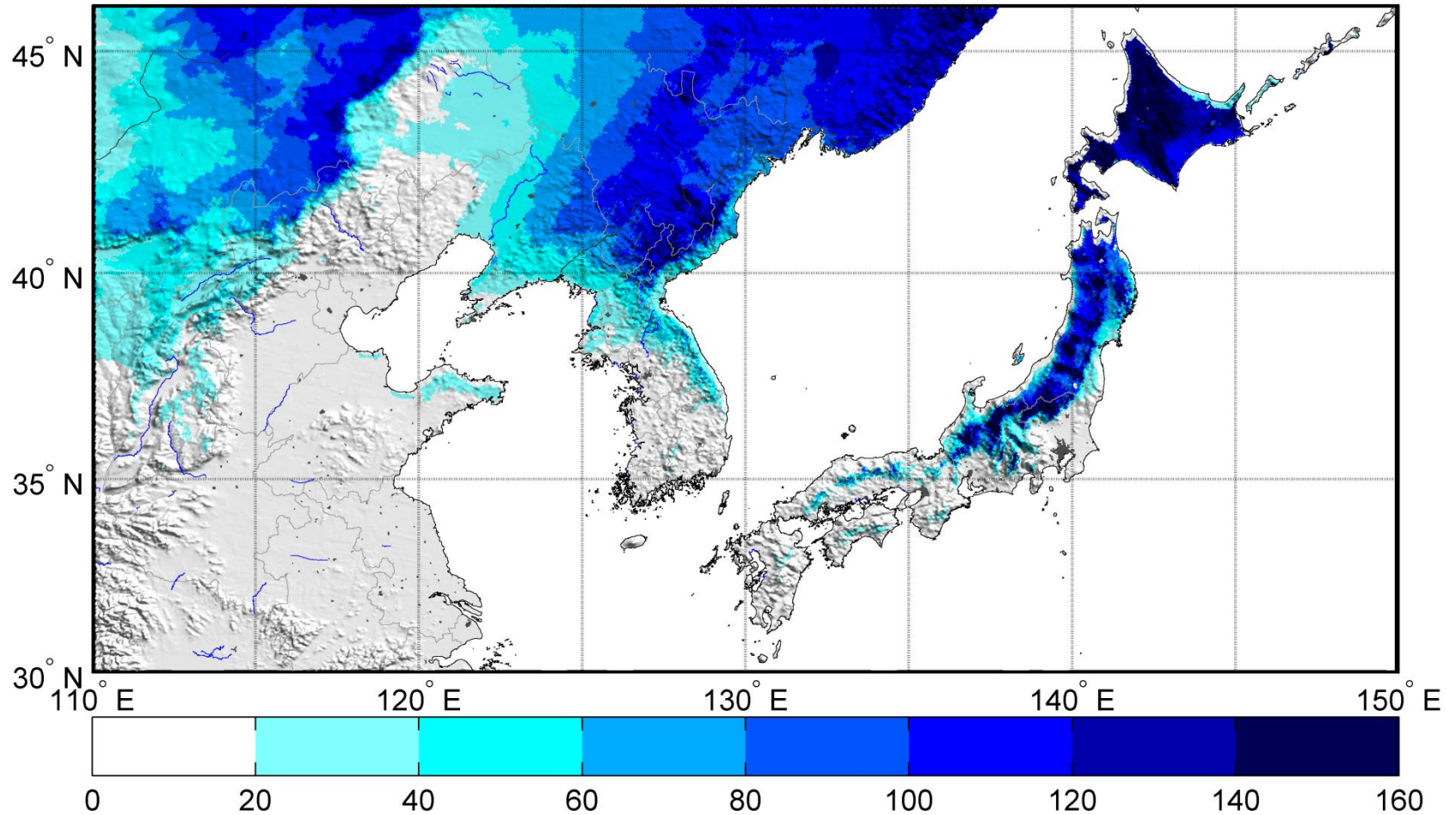
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Dezember 10

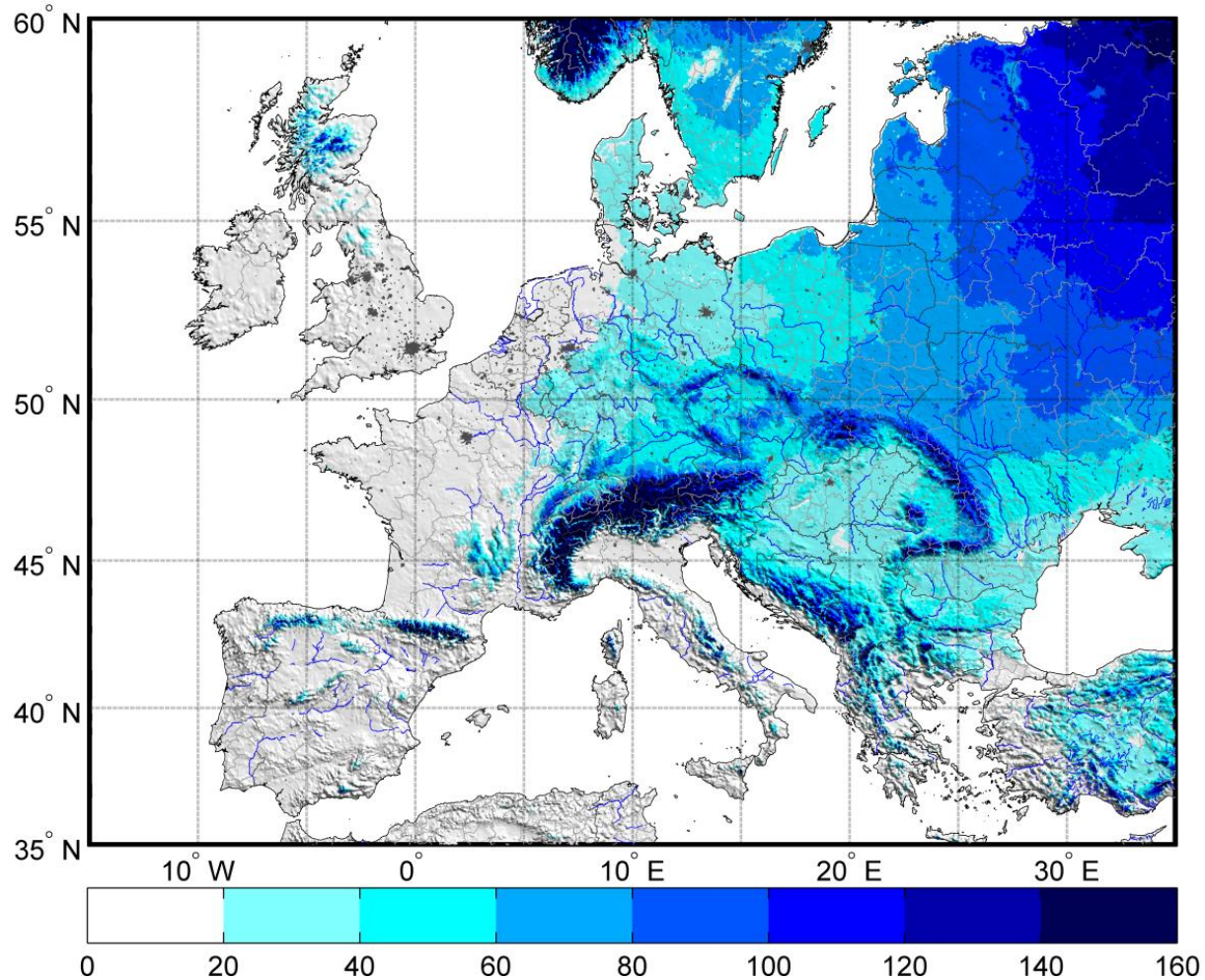
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# Yearly Snow Cover in Asia



# Yearly Snow Cover in Europe



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# Yearly Snow Cover in the US

